Biodiversity and Geneflow

Environment, Biodiversity and Geneflow

Some claim that GE crops offer environmental advantages over conventionally produced organisms like fewer and less toxic chemical herbicides and insecticides applications. However critics believe that GE crops are difficult to control and greatly increase the potential for escaping into the environment, crossbreeding with wild species and generally disrupting the natural ecosystem. Here we go through important biosafety issues for potato introduction into the environment and centers of origins.

Horizontal gene transfer to microorganisms

By definition this is the transfer of genes between plant species and between plant and non-plant species without sexual transmission. Naturally occurring vectors such as Agrobacterium tumefaciens, viruses, transposable elements and the degree of gene homology (causing recombination) are some of the factors that could have a role in these processes.

It is theoretically possible for microorganisms to incorporate DNA from transgenic potato plants in their own genetic material. However, such events have only been accomplished under optimized laboratory conditions and at a very low frequency. The probability of this kind of events occurring in nature and concerning the transfer of whole functional genes is extremely low.

There is also no evidence that the transferred genes from GM potato would be functional and hence would persist into the new host. In addition, processing of potato food is unlikely to maintain intact entire genes. Therefore, at this stage of our knowledge, the research on horizontal transfer of transgenes from plants to bacteria has not provided evidence that would qualify Horizontal gene transfer as a risk. Out crossing with wild relatives or cultivated varieties Gene flow from GE potato varieties to wild relatives could occur via outcrossing (Celis et al. 2004). From the southern US to Chile and Argentina, a continuum of wild potato species is present, and potato landraces occur primarily throughout the Andean region. These comprise a total of eight cultivar groups of four different ploidy levels and inter-specific hybrids with undefined taxonomic unit affiliation, as well as 199 wild species; in total these provide numerous opportunities for sexual crossing. Outside the Americas, no sexually-compatible relatives have been reported in potato growing areas.

Therefore, the issue of impact on biodiversity of gene flow through pollination is relevant mainly, if not only, in its the potato centers of origin and diversity. (Spooner and Hijmans, 2001).

A careful assessment though, is required for different potato species, of their respective ability to cross. This crossability of cultivated potatoes is dependent on several interplaying pre- and post-fertilization events that complicate crossability in potato:
Stylar barriers (evidenced by pollen stoppage in stigma or upper quarter of the style) in interspecific crosses (Fritz and Hanneman, 1989). Incidence of stylar barriers increases if the putative evolutionary distance of a wild potato species from a particular cultivated potato increases. This means that seed set and ease of seed production in hybrids between wild potato species and cultivated species decreases if the putative evolutionary distance between the two is larger.

Althought, ploidy barriers in interspecific crosses may prevent hybridization. Endosperm Balance Numbers (EBN?s) should be in ratio of 2:1 maternal to paternal in the endosperm for successful seed set (Johnston et al., 1980). Presence of 2n gametes may allow a species to overcome stylar, ploidy and EBN barriers. An extensive study (Jackson and Hanneman, 1999) confirms that crossability of wild potato species with cultivated species is highest in regions that are a major center of diversity for the cultivated potato. These major areas of diversity of potato are the
Bolivian and Peruvian Andes and the Northwest of Argentina, and Mexico. Therefore it seems logical that the introduction of new transgenic varieties should be done with the greatest care in these centers of diversity, if it should be done at all.

In the United States and Canada, few species exist that are basically isolated geographically and by crossability barriers from production areas. The risk of transgene escape into native potato populations here is extremely unlikely (Love, 1994). However, in the above-mentioned origins of diversity of potato, many wild species exist with ploidy level and EBN's compatible with those of the most common cultivated potatoes. This means that in that case the transgenic potato is able to cross with these wild species. The potential for further gene exchange also has to be noted. Because of the ploidy-series and the prevalence of 2n gametes among the tuber-bearing
Solanumspecies, the situation of gene flow may be even further complicated.

The question is whether natural conditions may be compared to experimental conditions, where thousands of crosses were made by hand under favorable circumstances, where fruit retention was promoted through the stem-cutting technique, and where species and cultivars were planted at varying times to provide a continuous source of flowers and pollen. (Frederick et al 1995). Cultivated potato species are known to have a very limited range of natural pollinator species, the bumblebee being the most important. This restricts their crossability. Generally, bumblebees travel only short distances, but occasionally may travel up to 5 km's (Jackson and Hanneman, 1999).

However, there is a variety of methods to restrict gene-flow between related species of potato:

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**Physical barriers**

- Barrier to pollen spread, like a border of non-engineered plants
- Restricted location and/or timing of crop planting
- Containment of genetically engineered crops

**Physiological barriers**

- Self-pollinating character of potato is a barrier on its own.
- Use of male-sterile genetically engineered plants (although this raises questions about the appropriateness of the technology for small-scale agriculture in developing countries, as small-holders often culturally depend on self-sustenance in seed access). The Russet Burbank cultivar used in North America, for example, does not produce viable pollen. It is genetically engineered with Bt-based insect resistance.
- Genetic engineering on plastids (which are not found in pollen).

The biological issues relating to transgene flow have already been discussed (Jackson and Hanneman, 1996; Frederick et al., 1995). The best means of containment are the avoidance of deployment of fertile transgenic varieties in centers of origin and diversity of the potato, the selection of areas where natural pollinators are not present, sterility in transgenic varieties. Thus it has been proposed that the region in which crossing can occur can be divided into areas, according to level of frequency, using species inventory and geographical information system techniques, as a means to concentrate on site-specific cases (Hijmans, pers. comm.). Recent gene flow study in Peru indicates that gene flow will occur in the long run in very specific areas, as is the case for landraces.

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**Impact on Biodiversity**
Gene flow is not a risk per se, it is its possible negative impacts on the (agro) bio-diversity which qualify as risk. The strength and the need of agriculture to cope with environmental changes and pests and diseases is the availability of diversity in the gene pool of a species.

Especially in areas which are centers of diversity of a species, great care must be taken for conservation of the required biodiversity.

For potato, such centers of diversity can be found in Mexico, and in the Andean regions of Peru and Bolivia.

Indeed, if hybridization of a transgenic species with a wild or other cultivated species or variety can, and does occur, then there is a possibility that certain transgenes may effect changes in diversity. This can happen if the transgene caused changes in fertility, fecundity, resistance, or susceptibility to pests. A transgene in a wild species therefore, may have an impact on the natural diversity in a particular region, or on a species through natural selection (Jackson and Hanneman, 1999).

There is debate over the issue whether transgenic plants are more likely to outcross than non-transgenic plants. Bergelson et al., 1998, describe a research that showed that some transgenic plants were indeed more ready to outcross then non-transgenic plants. However, the generality of these outcomes can be doubted. It is still unclear whether enhanced outcrossing is a recurring phenomenon in transgenic species and varieties.

However, it has often been brought forward that transgenic varieties have an intrinsically reduced capacity to invade natural ecosystems, because their acquired transgene (e.g. pest or disease resistance) in absence of selective forces has cost these plants a substantial fitness loss. Different independent research that aimed to measure this fitness loss in absence of selective forces has however, not been able to securely proof this assumption. The mixed results from these experiments have therefore undermined the strength of the argument (Ewel et al., 1999).

If a transgene with a dominant feature is released in a center of origin or diversity, and where farmers actively conserve landraces through the use of tuber seeds, then farmers may be expected to abandon the conservation of their landraces. This may also be a possible process of loss Naturalization.

**Naturalization of agro-biodiversity.**

The process of naturalization of a GM potato cultivar involves the fitness for and survival of the cultivar in the natural environment (outside of the farmers fields). This process is also referred to as? weediness? or invasiveness? of cultivated varieties.

Invasive species have been categorized as one of the most pressing environmental problems. Are transgenic potatoes more invasive than their conventional counterpart, or can transgenic potatoes be expected to be weedy at all? To answer these questions, we should first understand the plant characteristics required in the formation of a weedy nature. These characteristics are the following:
• Seed production in a wide range of environmental conditions.
• Discontinuous germination (internally controlled) and great longevity of seeds.
• Rapid growth through vegetative phase to flowering.
• Continuous seed production for as long as growing conditions permit.
• Self-compatible but not completely autogamous or apomictic.
• Cross-pollinated by unspecialized visitors or by wind.
• Very high seed production in favorable environmental circumstances.
• Adaptations for short- and long-distance dispersal.
• If a perennial, vigorous vegetative reproduction or regeneration from fragments.
• If a perennial, brittleness, so not easily drawn from ground.

Ability to compete interspecifically by special means (rosette, choking growth, other).

Although there is no weed that combines all these characteristics, a good number of these characteristics must be combined in order for a plant to develop a weedy nature. Potato is represented by a large number of wild species. Hawkes (1990) described 235 wild species of which 7 are cultivated. The wild relatives can be found in a geographical area running from the Southwestern USA and Mexico, through Central America into South America, following the mountain chains. They are found in diverse ecological conditions ranging from arid desert-like climate to wet and humid, mountain forest climates, and even they are found as weeds of cultivation (Jackson and Hanneman,1999). However, none of the cultivated species are known to behave as weeds.

Wild species sometimes found as a weed in soybean and wheat cultivation(Fig.2 y Fig.3).

![Fig.2 Solanum elaegnitolium](image1) ![Fig.3 Solanum carolinense](image2)

Few GM potato varieties exist to date. These are all derived from commercially known varieties that are known not to exhibit weedy character. These commercial varieties hardly produce true seeds. Newleaf?-potato (resistant to Colorado beetle) for example, has not been found to exhibit increased weediness because of its DNA insertion safety assessment of NewLeaf Y Potato and Safety assessment of NewLeaf Plus Potato. Weediness of potato however, is only more likely to occur in varieties bred through conventional breeding or, as it was discussed in the paragraph below, after possible outcrossing of a GM variety with wild varieties.

Many plants eaten as vegetables make an exaggerated effort to produce leafy or root and tuber parts, and only feebly make flowers and seeds. In addition, humans probably chose in the first place the crop plants we use today in part because they are so well behaved in human society and only grow where they are supposed to grow. There are some exceptions, however: sugar beets, for example, brought to the US from Europe, have in some areas of California escaped from farmer's fields and now grow in small "wild" populations. Almost without exception,
cultivated crop plant are not and do not become weeds, because these and other fitness traits are compromised. For cultivation, we prefer large, starchy seeds with thinner coats (easier to digest); seeds that stay attached to the plant (easier to harvest); seeds that don’t go dormant and that sprout almost as soon as they hit the ground (easier to plant); larger fruit with fewer (or no) seeds (easier to eat); etc.

The fear that genetic engineering, with the addition of a single or a couple of genes, will create a weed should not be waved aside, but is mostly based on assumptions that have yet to be proven.

Multiple genes code most of the weediness characteristics, and this makes it highly unlikely that the introduction of a single gene into an otherwise non-weedy species will suddenly make it weedy.

None of the traits currently engineered into plants appear to alter the plants’ ability to overcome their built-in escape barriers. In a recent ten-year study with some of the most commercially released GM varieties to date, four different crops (oilseed rape, potato, maize and sugar beet) were grown in 12 different habitats and monitored over a period of 10 years. The study determined that the GE varieties are no more likely to grow outside an agricultural field than their non-GE counterparts. In other words, in no case did the GM lines persist for significantly longer than their conventional counterparts (Crawley et al., 2001).

However, if in the future the traits engineered into plants become more complex, it may be difficult to predict their weediness from the trait alone. More complex GE plants may require careful and cautious pre-market field-testing, and additional vigilance once the plants are released commercially.

References:


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